IMPLEMENTATION OF NATIONAL SCIENCE FOUNDATION BROADER IMPACTS CRITERION FROM 1997-2017

by
Angela M. Green

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ABSTRACT

Objective- The objective of this paper was to evaluate the implementation of the broader impact criteria from its inception, over three distinct time periods to today.

Methods- Using data retrieved from the awarded/completed projects on the website Research.gov, thirty randomly selected projects from each of the three time periods, 1997-2006, 2007-2012 and 2013-2017 were evaluated to determine if the projects accomplished the specified broader impact listed in the proposal. Each project was given a score using the following scale: 1-Does not achieve Broader Impact Criteria, 2-Barely achieves Broader Impact Criteria, 3-Achieves Broader Impact Criteria, 4-Exceeds in fulfilling Broader Impact Criteria, and 5-Significantly exceeds fulfilling Broader Impact Criteria.

Results- The results of the analysis indicated that there were differences in the effectiveness of achieving the broader impact criteria over the three time periods. Later time periods had a statistically significant better score. Additionally, it was found that there was a greater consistency in meeting the criteria in the later periods.

Conclusions- Despite the fact that there have been improvements in achieving the broader impact criteria, there remains room for additional improvement.

Thesis Advisor: Dr. Jeffrey Kantor

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INTRODUCTION

Yearly, the National Science Foundation receives approximately 40,000 proposals requesting funding. The process for receiving funding is very competitive and roughly, 11,000 projects are sponsored. To determine which projects to support, NSF applies two criteria in the merit review of proposals: intellectual merit and the broader impact of the proposed project. Both of these criteria must be included in the proposal to receive funding. "While most researchers know what is meant by Intellectual Merit, experience shows that many researchers have a less than clear understanding of the meaning of Broader Impacts (National Science Foundation, 2007, pg. 1)."

The implementation of the National Science Foundation criteria for broader impact began in 1997 with intellectual merit and broader societal impact. In 2007, after evaluating the criteria an emphasis on transformative research was established.

Transformative research involved research that was revolutionary, leading to advances, breakthroughs, inventions and new findings.

A Task Force on Merit Review further assessed the validity of the measures in 2010 and reaffirmed both criteria intellectual merit and broader societal impact. Researchers continued to have apprehensions related to broader impacts criterion and the inconsistencies in its application. The task force asked for responses on the merit review process and received 5100 remarks. The

remarks indicated that some researchers felt that forcing them to participate in outreach efforts would hinder their research. Additionally, they were concerned over structuring science by what society felt was of national concern (Revised Merit Review, 2013).

In 2011, the National Science Board revised the criteria by revamping the goals. They endorsed the two merit review criteria and added three merit review principles. These principles included that NSF projects must be of high quality with the possibility of making advancements in science. Additionally, the projects must continue to strive toward benefiting society. Lastly, the projects must be evaluated based on a set of metrics.

The topic of broader impact continued to be a source of perplexity for researchers and in 2013, NSF published a revision to the merit review criteria and created elements as listed below.

> "Three review principles: 1.) All NSF projects should be of the highest quality and have the potential to advance, if not transform, the frontiers of knowledge, 2.) NSF projects, in the aggregate, should contribute more broadly to achieving societal goals and 3) Meaningful assessment and evaluation of NSF funded projects should be based on appropriate metrics, keeping in mind the likely correlation between the effect of broader impacts and the resources provided to implement projects. Two review criteria: 1.) Intellectual Merit: The intellectual Merit criterion encompasses the potential to advance knowledge; and 2.) Broader

Impacts: The Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific, desired societal outcomes.

Five review elements: 1). What is the potential for the proposed activity to: a. advance knowledge and understanding within its own field or across different fields (Intellectual Merit); and b. benefit society or advance desired societal outcomes (Broader Impacts)? 2.) To what extent do the proposed activities suggest and explore creative, original, or potentially transformative concepts? 3.) Is the plan for carrying out the proposed activities well-reasoned, well organized, and based on a sound rationale? Does the plan incorporate a mechanism to assess success? 4.) How well qualified is the individual, team, or institution to conduct the proposed activities? 5.) Are there adequate resources available to the PI (either at the home institution or through collaborations) to carry out the proposed activities? (National Science Foundation, 2007, pgs. 1-2)."

The history and NSF's philosophy behind the broader impacts concept was to create a federal government that was responsive and accountable to its citizens. Despite the efforts made by the National Science Foundation over the last twenty years to enforce the inclusion of a broader impact for all NSF projects, confusion has and still exists.

REVIEW OF LITERATURE

The American Physical Society Sites' APS News exemplified the views of many in the research community in their article, "NSF's "Broader Impacts" Criterion Gets Mixed Reviews." The article stated, "The broader impacts requirement is supposed to promote education, outreach, and benefits to society, but some scientists view the criterion as confusing, burdensome, inappropriate, or counterproductive (NSF's Broader Impact, 2007, pg. 1)."

Issues of concern for many researchers focused on research vs. outreach. Although, they indicated that outreach was good, they did not agree with it being a funding requirement. Additionally, many expressed that funding decisions should focus on the merit of the research and not outreach efforts.

Another problem researchers had was the lack of direction given by the National Science Foundation in regards to appropriate ways to achieve the broader impact. The instructions for many were too elusive. Researchers were unsure of the necessary number of broad impacts needed per proposal.

For new researchers, trying to add a broader impact to their research was very difficult. These researchers were struggling to get funding and adding this dynamic to the process made it even harder. The NSF's Broader Impact article also illustrated how a woman pursing funding was already achieving the criteria

of promoting diversity by merely existing; however, because of this mandate by NSF was required to provide another broader impact (NSF's Broader Impact, 2007).

A valid point made by Melanie Roberts the author of, "Realizing Societal Benefit from Academic Research: Analysis of the National Science Foundation's Broader Impacts Criterion," was whether researchers actually achieved their research broader impact. In her study "benefit to society" was defined as transferring information in a format that was useful to others. Melanie found that "although 43% of researchers discussed potential benefits for society, those researchers were no more likely to propose dissemination of results to potential users than researchers who only discussed broader impacts for science (Roberts, 2009, pg. 1)." The result of her study showed that whereas researchers have listed in their proposals that their work was going to be a benefit to society this was not necessarily the case.

In 2010, another article which also conveyed the confusion some had over broader impacts was Corie Lok's "Science for the Masses: The US National Science Foundation's insistence that every research project addresses 'broader impacts' leaves many researchers baffled." Ms. Lok argued that research funding agencies have to mindful of two challenging factors, researcher's autonomy and the public's desire for science to have societal benefits (Lok, 2010).

One of the key points included in her article was the suggestion that there was a lot of effort focused on creating opportunities for broader impact activities without knowing if these activities were making a difference. The article further demonstrated why researchers believed that the criteria were confusing. NSF attempted to give independence to the researchers by not being rigid with the broader impact criteria; however, they actually caused researchers to be confused. The inference being that many researchers wanted the directions to be specific and clear with the exact requirements listed with no ambiguity (Lok, 2010).

The article further implied that the misperception would continue to exist, without clarity on what broader impacts needed to be included in the proposal. Likewise, there definitely needed to be a way to track the advances made through these impacts and the funding amounts associated with them.

Daniel Sarewitz's article, "The dubious benefits of broader impact," expanded on the inefficiencies surrounding the concept of broader impact. He thought that the criteria of broader impact were politically motivated and designed to justify government expenditures in research. He further suggested that forcing researchers to create opportunities for broader impacts was a worthy goal, but the facilitation process was not appropriate and would inevitably cause "cynicism and hypocrisy (Sarewitz, 2011, para. 11)."

Sarewitz also exposed the complications with peer reviewers' evaluations. He maintained that many would not have the expertise to conclude if the impact had the possibility of being successful. The article concluded with his perspective on direct approaches that would create opportunities for projects to have a broader impact.

His concept included the National Science Foundation becoming creators of programs that would have a broad impact on society. Sarewitz concluded that researchers would become participants in the programs.

The article, "Science: For Science's or Society's Sake? Owning the National Science Foundation's Broader Impacts Criterion," also addressed the issue of taxpayer's return on their investment. Holbrook and Frodeman, agreed that, "Researchers have resisted NSF's Broader Impacts Merit Review criterion since its inception, arguing that it was irrelevant, impossible to answer, or, most commonly, just plain unclear (Holbrook & Frodeman, 2012, para. 1)."

Despite the revisions, the authors suggested that the criteria were still vague. However, what was interesting was that while the authors showed how the criteria were still considered as being unclear, they explained how the National Science Board interpreted the vagueness as giving the researchers freedom to explore their ideas, which would lead to a broader impact.

"An enduring image of academia is that of an ivory tower, disconnected

from the messy problems of the world (Naggy, 2014, para. 1)." Dr. Dianne Naggy, of South Dakota University used these words to begin her article, "Determinants of Broader Impacts Activities: A Survey of NSF-funded Investigators." Her study looked at the influences that created the investigator's perception on the NSF's criteria of broader impacts. Some of the leading issues investigators had with the criteria were lack of training in this area, lack of desire to implement the impact, and lack of assistance from their institutions (Naggy, 2014).

"How broad are our broader impacts? An analysis of the National Science Foundation's Ecosystem Studies Program and the Broader Impacts requirement," an article written by Nalini M. Nadkarni and Amy E. Stasch analyzed the proposed broader impacts listed in funded Ecosystem Programs. The article stated that only 65% of the proposals actually had a broader impact statement. The authors recommended that NSF needed better enforcement of the broader impact criteria by developing procedures to make investigators accountable (Nadkarni & Stasch, 2013).

Not only were there issues with how to determine the broader impact, but researchers also questioned the peer reviewers' knowledge on broader impact. Peer reviewers judging areas in which they too were novice definitely was a problem that bothered researchers. This problem was addressed in the article,

"How Much Broader Impact? The debate over NSF's broader impacts requirement in grant proposals heats up at a congressional hearing "(Scudellari, 2011). In the article Megan Scudellari discussed, that a Vice Chancellor from one university has echoed the sentiment that peer reviewers did not have the proficiency to judge broader impact. The Chancellor also commented how broader impacts cannot be determined at the beginning of the project (Scudellari, 2011).

Another article that observed the effectiveness of achieving broader impact was Watts, George and Levy's, "Achieving Broader Impacts in the National Science Foundation, Division of Environmental Biology." The authors advocated that communication was an important element in achieving the broader impact. The key takeaway from this article was that the research community wanted to be informed. This included actually receiving information about policy changes and any decisions that affected the broader impact criteria. The authors also realized the importance of NSF and academic institutions working together to reduce researchers' burdens (Watts, George & Levey, 2015).

Helping researchers gain a clearer understanding of the broader impact criteria has been the focus of numerous publications. The Principal Investigators' Association publication, "NSF Criteria: Communicate Your Broader Impacts Successfully," addressed the uncertainty that some researchers have with the policy.

This publication discussed ways to establish the broader impact criteria. The author mentioned that due to the complexity of the broader impact criteria, researchers struggled with integrating into their proposals (NSF Criteria, n.d.).

The publication gave directions on how to communicate the broader impact criteria in an NSF acceptable manner. Suggestions included that the broader impact should have an identified impact of change, which should result in an impact chain. The authors described the impact chain as developing educational experiences and innovation that generated more opportunities, collaborations which are shared within the discipline. The article listed two key areas for generating appropriate broader impact criteria: understanding and communicating (NSF Criteria, n.d).

There was overwhelming research, which indicated that there were definitely mixed feelings with regard to the criteria. Some lacked understanding of the meaning of the criteria, while others had a negative opinion concerning its necessity and the purpose behind it.

Further evidence that verified the lack of understanding of the meaning of the broader impact criteria was the necessity to have national summits to discuss broader impacts. Yearly national summits are conducted to discuss the future of the national broader impacts community, and, most importantly, to dialogue about the future of broader impacts.

The focus of the initial meeting held in 2013 was to create an infrastructure for support of broader impacts. NSF's vision, "NSF envisions a nation that capitalizes on new concepts in science and engineering and provides global leadership in advancing research and education (See, 2013, pg. 3)." Because of the 2013 summit an organization, the National Alliance for Broader Impacts was established. The organization's mission was to provide an association that would cultivate the concept of broader impacts.

In 2014, the summit had a three-fold purpose: to increase broader impact collaboration, improve broader impact learning, and influence broad impact policies. An additional organization BIONIC was created. BIONIC stood for the Broader Impacts and Outreach Network for Institutional Collaboration (BIONIC). NSF as a support system established this organization for those who required aid in incorporating broader impacts in their proposals.

In 2015, the posters from the summit implied that many institutions had begun creating the infrastructures to help with broader impact criteria. The 2016 summit centered on broadening participation and included sessions on approaching broader impacts from an institutional level. An interesting topic for the 2017 Broader Impact Summit was the inclusion of a workshop discussing how to evaluate the broader impact criteria (National Alliance, n.d.).

Although, the summits appeared to be addressing some of the concerns within the research community with regard to the broader impact criteria, many researchers remained in opposition of it being a requirement. Upon researching the list of members that supported these summits and were members of NABI, some of the notable institutions did not appear on the list such as Johns Hopkins University, University of Michigan and University of California (National Alliance, n.d.). These institutions are listed in the top ten universities for R&D expenditures for 2015. As one of the top ten universities for Research and Development, it would seem as though they should have actively participated in the discussions on broader impacts. Although membership to NABI was free, only 100 or so institutions were members (National Alliance, n.d.).

Was not being a part of the discussion contributing to the confusion? In Judith Hallinen's dissertation, "The many quiet tensions: Perceptions of the broader impacts criterion held by NSF career award holders at very high research institutions of higher education," she eluded to the fact that many times senior faculty gave mixed messages to junior faculty in reference to the importance of the broader impact criterion. This left the junior faculty perplexed about how much time and effort they should spend on the broader impact criterion (Hallinen, 2014).

As indicated in the literature varied opinions about the importance of the broader impact criteria are prevalent. Attitudes toward incorporating the criteria

in research are rooted for some in the obstacles that many have faced when they try to create opportunities of outreach.

The literature showed many researchers felt that they did not have the support of their institution, having to conduct research and outreach was too cumbersome, and they did not know how to make the correlation between research and outreach. What was also interesting was that studies showed that there was a "generational gap" between younger and older researchers. Younger researchers were more eager to create outreach opportunities that benefit society than their older mentors. Perhaps this generational gap in some circumstances added to the problem.

Through the literature review, it was evident that the purpose of the inclusion of the broad impact criteria was to justify the investment the government has made in the National Science Foundation. As a Federal agency, the NSF has to ultimately answer to the public for how it spends its funding. Requiring the broader impact criteria was a mechanism for NSF to validate their transparency to the public.

Public Trust in government has been on a decline. For example, in May 2017, only 20% of Americans believed the government was making appropriate decisions.

Many researchers thought that strengthening the public's trust in research was the foundation for instituting policies like broader impact criteria.

NSF officials have stated at the summits that it was important to keep Congress and other stakeholders informed of pertinent NSF funded projects. Having a broad impact requirement served as a way to share the activities that were designed to benefit society and lead to societal advances. Disseminating this information would inevitably promote public trust.

In the article, "Scientific Research and the Public Trust," the author presented a perspective on public trust and its real meaning:

> "Well-focused arguments that use public trust to support rules or policies for the conduct of research should specify a) which public is being referred to (e.g. the general public or a specific public, such as a particular community or group); b) what this public expects from scientists; c) how the rule or policy will ensure that these expectations are met; and d) why is it important to meet these expectations (Resnik, 2011, pg. 1)."

The "public" referenced in the NSF requirement for broader impact criterion has been the nation. In NSF's desire to satisfy the demands of Congress, they have created rules that forced researchers to perform research that have a broad impact. Even though, the researchers have shared complaints with regard to it being exhausting and it has been evident that they do not necessarily

accomplish the impacts in their proposals, the requirement continued to be expected.

The literature has shown that there are diverse reviews about broad impact requirements. While NSF promotes them as way to obtain the public trust, many believe public trust comes from engaging with the public not merely communicating with them. Engaging leads to ideas such as community based research initiatives and mentoring projects. As indicated previously, many consider the mandate a conflict between research and outreach.

Should scientist be forced into outreach efforts? There were pros and cons for both beliefs. Perhaps a forced marriage between the two would make researchers stretch themselves. It would make them look at research in a different manner. Also, it would create a connection from the science to the people. Since tax dollars are supporting the research there definitely needed to be some accountability for the expenditures.

On the other hand, should the NSF make outreach a requirement for a researcher whom lacks commitment in this area? Would that researcher treat the requirement with the dedication it deserved? Furthermore, would trying to accomplish the broad impact goal interfere with the actual purpose of the project?

The inclusion of the broad impact criteria in proposals has been mandated; however, was that mandate actually occurring? Did researchers consider the broad impact requirement on the same level as their intellectual merit or was it an after- thought?

PROBLEM STATEMENT

While, the driving force behind the National Science Foundation's broader impact criteria was "achieving public trust" and "spending federal money wisely", effectively accomplishing this task by implementing the criteria still remains a current topic of discussion. The objective of this paper was to investigate the implementation of the broader impact criteria from its inception to the current day. The aim was two-fold, 1.) to evaluate researchers' responses to the broader impact criteria during specified time periods 2.) to assess whether there were differences in how effective the researchers were in meeting their proposed criteria across the three time periods.

RESEARCH METHODOLOGY

The research procedures included examining thirty NSF awarded and completed projects from 1997-2017 to evaluate the proposed versus reported broader impact, based on particular periods when changes occurred to the broader impact criteria. Specifically, examining if the researcher achieved the impact outcome contained within the proposal.

The Research.gov website was the source for this search**.** This website contained information related to research spending which included the proposal abstract, the funding amount and the program outcome. Within the proposal abstract, the intended broader impact was stated. Likewise, the program outcome listed what broader impact was accomplished. Utilizing the program outcome data, the website was queried using keywords "benefit to society". "Benefit to society" was chosen because it was one of the five NSF broader impact areas and was the terminology, which appeared most frequently in the literature about broader impact. The other areas included advance discovery and understanding while promoting teaching, training and learning, broaden participation of underrepresented groups, enhance infrastructure for research and education, broad dissemination to enhance scientific and technological understanding.

The data for the study included a random selection of projects between 1997 and 2017 with funding amounts ranging from 900,000 to 1,000,000. The procedure for selection involved completing three separate searches for each period (1997-2006), (2007-2012) and (2013-2017). The decision to choose the above-specified periods corresponded with time points when NSF refined intellectual merit and broader impacts. There were three distinct periods: Intellectual Merit & Broader Impacts (1997-2006), Emphasis on Transformative

Research in Intellectual Merit & Broader Impacts (2007-2012) and Revised Intellectual Merit & Broad Impacts (2013).

To achieve a random group of projects for each period, the selection process comprised using the random.org website for selection of ten numbers. Then ten numbers were chosen out of the number of projects per period for each period. There was an evaluation of the ten projects from each period. The number selected from random.org determined the project numbers to choose for assessment from the listing.

After selection, two raters independently rated each program. One rater was a master's graduate with experience in project management. I was the other rater. Each rater reviewed the definitions that were in effect for broader impacts for that given period. The rater read the abstract, program outcome for all projects, and reviewed the program outcome data for each project. Detailed instructions for each time period that explained the criteria and definition for the broader impact (see appendices, Instructions to Rater) were given to the rater.

For every time period, each project was scored based on how effectively the project achieved their proposed broader impact. The success of each project to achieve the proposed broader impact, was scored on a five-point scale: 1-Does not achieve Broader Impact Criteria, 2-Barely achieves Broader Impact Criteria, 3-Achieves Broader Impact Criteria, 4-Exceeds in fulfilling Broader Impact Criteria, and 5-Significantly exceeds fulfilling Broader Impact Criteria.

For each project, a two-step rating system was used. First, each rater decided if the data indicated that the broader impact was met. If the criteria was not met the project was given a score of one. On the other hand, if the criteria was met, the rater then scored the proposal using the five-point scale listed above.

A spreadsheet with the project name, date, funding amount, proposed broader impact, achievement of broader impact and score was used to document the scoring. Using the above five-point scale, for each period, a mean score was calculated.

DATA ANALYSIS

Statistically significant differences across the groups were evaluated by an analysis of variance testing which examined the differences across time period means. Using the statistical data analysis package Stata, Levene's robust test statistic for the equality of variances between the mean score of the three time periods was calculated (Levene, 1960). In Stata, the command that was used was the "robvar" command because there were more than two groups to compare. Additionally, to detect if there were differences among the pairs of means from the different time periods, Tukey's HSD Test was performed. Variability across the time periods was evaluated for statistical differences by conducting Bartlett's Test.

RESULTS AND DISCUSSION

Results

The overall analysis of variance indicated that there were significant differences, $p<.01$, among the mean broader impact scores (see appendices, Table 1). The findings from the Tukey pairwise comparisons confirmed that significant differences were found between time periods (1997-2006) vs. (2007-2012) as well as (1997-2006) vs. (2013-2017), (see appendices, Table 3). Across the time periods the variances were not equal (see appendices, Table 2). The variability decreased from time period (1997-2006) to time period (2013-2017), (see appendices, Figure 1).

DISCUSSION

The data demonstrated that there has been an improvement in the implementation of the broader impact criteria. The mean score for time period one (1997-2006) was 2.5. Whereas, the mean scores for time periods two (2007-2012) and three (2013-2017) were 3.8 and 3.9 respectively. The mean score of 2.5 supported the belief, that many researchers were confused by the criteria. The actual review of the data endorsed this belief as well.

Many of the researchers struggled to list the broader impact in their abstracts and it was at times very hard to distinguish how the impact had been accomplished in the project. During this period, literature showed that many

researchers commented on the ambiguity of the definition of broader impact. This confusion was reflected in the abstracts and program outcome reports. Many program outcome reports did not clearly state the broader impact of the project. It had to be inferred by what was listed in the abstract and what was stated as being completed in the project.

The 2007-2012 time period showed a remarkable improvement in the mean score. The broader impact mean score for this time period was 3.8. The notable improvement in the mean score for the broader impact reflected the emphasis that was being placed on inclusion of a broader impact. Transformative research was being highlighted. Throughout this time period, major emphasis was being placed on the broader impact criteria. Additionally, a task force reassessed and reaffirmed the validity of the measures. The task force also engaged researchers in a discussion regarding the review process. The data reviewed reflected the progress. It was easier to make a comparison between the broader impact listed in the abstract versus the program outcome report. In many cases, it specifically was stated broader impact.

There continued to be a positive trend in the broader impact score during 2013-2017. The broader impact mean score was 3.9 for projects that were reviewed. This score coincided with the 2013 NSF new criteria that was published. The new criteria provided additional details and an in depth listing of what was being evaluated. Additionally, at this time NSF began having

summits/conferences related to Broader Impact, universities established offices designated to help those who had problems with broader impact and organizations that focused on broader impact were created.

The data that was examined during this time period exhibited that there had been improvements. The abstracts clearly listed the broader impact and the program outcome reports had broader impact statements.

As predicted the latter time period had higher mean broader impact scores. On a 100% scale, a score of 3.9 would be considered 78% or a C+. Therefore, the evaluated data indicated that researchers at this time adequately met their broader impact criteria. Thus, leaving room for improvement.

CONCLUSION

Communication as mentioned earlier was one of the key areas that needed improvement. "Greater internal communication among NSF directorates and divisions would help disseminate innovations for enabling broader impacts, as well as lessons learned from past practices (Watts, George & Levey, 2015, pg. 10)."

While, there have been many measures taken to improve the way the broader impact criteria was viewed and to determine new mechanisms for this task, changes are still needed. On the university level there have been several

initiatives taken to make the broader impact criteria less ambiguous for researchers.

These initiatives included creating websites to help understand the term "broader impact" criteria. The websites included suggestions of steps to take to develop a broader impact plan, instructions on how to specify the impact in the proposal, links to resources for broader impact as well as potential partners for broader impacts. Additionally, on many sites frequently asked questions were answered.

Some universities have also set up offices to handle broad impact criterion issues. Moreover, some institutions have elected to have seminars with broad impact criteria as the topic of discussion. All of the above are excellent and should continue to be done.

One of the most important aspects of fulfilling a task is when one is accountable for that task. Although, NSF mandated that broader impact criteria must be included in proposals, I have not found were these broader impacts are being audited by NSF. Researchers submit abstracts, these abstracts are funded and when completed the investigator/researchers supply NSF a program outcome report. Perhaps if it was known that upon project completion, the program outcome report would be audited, the quality of the broader impact would improve, be clear and be attempted. Because of the nature of research a

project may not be able to accomplish the broad impact; however, if listed there should be documentation that the impact was attempted.

Additionally, to ensure that the broader impact does not become a repetitive statement, it may be worthwhile to ask questions on why the researcher has chosen this area of impact. This would show their commitment, dedication and interest in the broader impact and perhaps lead to higher broader impact implementation.

REFERENCES

APPENDICES

Table 1

Summary of Broader Impact Score Levene Test

Group	Mean	Standard Deviation	Frequency
1 (1997-2006)	2.5	1.3178931	20
2 (2007-2012)	3.8	.7677719	20
3 (2013-2017)	3.9	.64072328	20
Total	3.4	1.1379434	60
W0 = 11.2246769	df(2, 57)	Pr > F = 0.0000776	
W50 = 6.3333333	df(2, 57)	Pr > F = 0.00328262	
W10 = 11.9193114	df(2, 57)	Pr > F = 0.00004735	

Figure 1 Standard Deviation Differences Across Time Periods

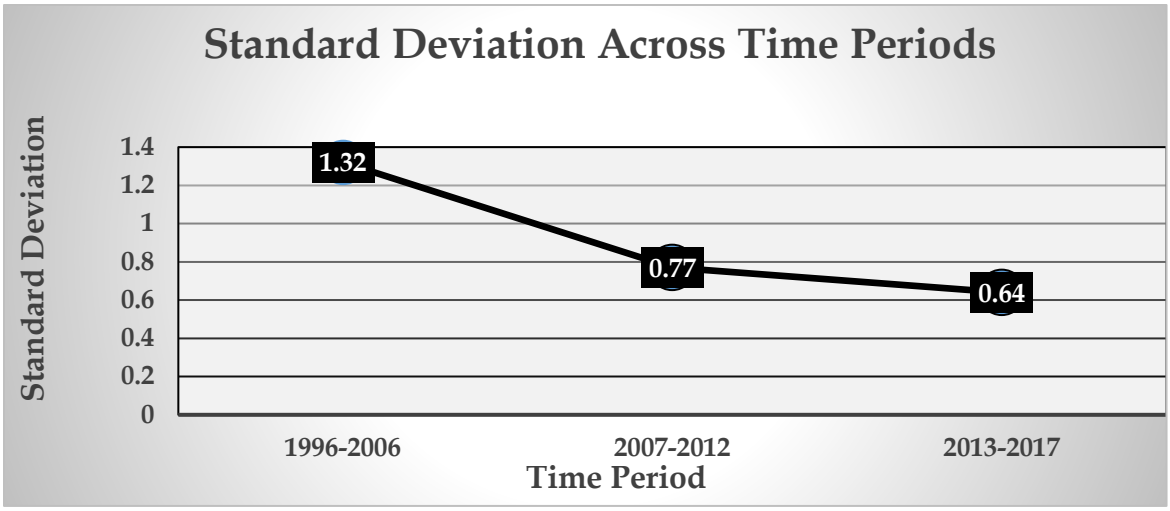

Table 2 Analysis of Variance (Bartlett Test)

Source	**SS**	**df**	**MS**	**F**	**Prob > F**
Between Groups	24.4	2	12.2	13.37	0.0000
Within Groups	52	57	.912280702		
Total	76.4	59	1.29491525		

Bartlett's test for equal variances: chi2(2) = 10.9788 Prob>chi2 = 0.004

Table 3 Tukey HSD Test for Post-ANOVA Pair-Wise Comparisons

	Group 1 (1996-2006)	Group 2 (2007-2012)	Group 3 (2013-2017)
Mean	2.5	3.8	3.9
N	20	20	20
MS error	1.29		
df error	59		
HSD .05	.87		
HSD .01	1.09		

Table 3a Pair-Wise Comparisons via Tukey HSD Test

	Group 2	Group 3
Group 1	P<.01	P<.01
Group 2		n/s
Group 3		

n/s= not significant

Instructions to Rater:
Attached are a random selection of projects completed prior to 2007 as well as a summary spreadsheet for the projects. Please review the "Program Outcomes" section and determine if the project appears to have fulfilled the broader impact criteria by stating yes or no. Additionally, determine to what degree the broader impact was satisfied.

Broader Impact Criteria definition 1997-2006.
"The following are suggested questions to consider in assessing how well the proposal meets this criterion: How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society?"

Five Point Rating Scale:
1-Does not achieve Broader Impact Criteria
2-Barely achieves Broader Impact Criteria
3-Achieves Broader Impact Criteria
4-Exceeds in fulfilling Broader Impact Criteria
5-Significantly exceeds fulfilling Broader Impact Criteria.

Instructions to Rater:
Attached are a random selection of projects completed from 2007-2013 as well as a summary spreadsheet for the projects. Please review the "Program Outcomes" section and determine if the project appears to have fulfilled the broader impact criteria by stating yes or no. Additionally, determine to what degree the broader impact was satisfied.

Broader Impact Criteria definition 2007-2013

Emphasis on Transformative Research in Intellectual Merit & Broader Impacts (2007-2013)
Transformative Research*

Merit Review Principles

Given that the NSF is the primary federal agency charged with nurturing and supporting excellence in basic research and education, the following three principles apply:

- All NSF projects should be of the highest quality and have the potential to advance, if not transform, the frontiers of knowledge.
- NSF projects, in the aggregate, should contribute more broadly to achieving societal goals. These "Broader Impacts" may be accomplished through the research itself, through activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project.
- Assessment and evaluation of NSF funded projects should be based on appropriate metrics, keeping in mind the likely correlation between the effect of broader impacts and the resources provided to implement projects. If the size of the activity is limited, evaluation of that activity in isolation is not likely to be meaningful. Thus, assessing the effectiveness of these activities may best be done at a higher more aggregated level than the individual project.

Broader Impacts: The Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific, desired societal outcomes.

Five Point Rating Scale:
1-Does not achieve Broader Impact Criteria
2-Barely achieves Broader Impact Criteria
3-Achieves Broader Impact Criteria
4-Exceeds in fulfilling Broader Impact Criteria
5-Significantly exceeds fulfilling Broader Impact Criteria.

Instructions to Rater:
Attached are a random selection of projects completed from 2013-2017 as well as a summary spreadsheet for the projects. Please review the "Program Outcomes" section and determine if the project appears to have fulfilled the broader impact criteria by stating yes or no. Additionally, determine to what degree the broader impact was satisfied.

Broader Impact Criteria definition after 2013
Three review principles:
1.) All NSF projects should be of the highest quality
and have the potential to advance, if not transform, the frontiers of knowledge
2.) NSF projects, in the aggregate, should contribute more broadly to achieving societal goals and
3) Meaningful assessment and evaluation of NSF funded projects should be based on appropriate metrics, keeping in mind the likely correlation between the effect of broader impacts and the resources provided to implement projects.
Two review criteria:
1.) Intellectual Merit: The intellectual Merit criterion encompasses the potential to advance knowledge;
2.) Broader Impacts: The Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific, desired societal outcomes.
Five review elements:
1). What is the potential for the proposed activity to: a. advance knowledge and understanding within its own field or across different fields (Intellectual Merit); and b. benefit society or advance desired societal outcomes (Broader Impacts)?
2.) To what extent do the proposed activities suggest and explore creative, original, or potentially transformative concepts?
3.) Is the plan for carrying out the proposed activities well-reasoned, well organized, and based on a sound rationale? Does the plan incorporate a mechanism to assess success?
4.) How well qualified is the individual, team, or institution to conduct the proposed activities?
5.) Are there adequate resources available to the PI (either at the home institution or through collaborations) to carry out the proposed activities?"
Five Point Rating Scale:
1-Does not achieve Broader Impact Criteria
2-Barely achieves Broader Impact Criteria
3-Achieves Broader Impact Criteria
4-Exceeds in fulfilling Broader Impact Criteria
5-Significantly exceeds fulfilling Broader Impact Criteria.

Broader Impact Spreadsheet

Program Title	Date	Funding Amount	Proposed Broader Impacts listed in abstract (yes or no)	Achieved Broader Impacts (yes or no)	Score 1-5
Special Programs in Astronomy CAREER: Order-of-Magnitude Problems in Star Formation and Minority Representation	5/5/2004	$ 939,034.00			
Gene Expression CAREER: Pre-mRNA Splicing and the Coordinated Network of Gene Expression Machineries	1/31/2005	$ 911,950.00			
FDSS: Space Science Faculty Development at Pennsylvania State	6/22/2005	$ 900,000.00			
MOLECULAR BIOCHEMISTRY: The Influence of Secondary Structure on the Folding Catalysis of Functional RNA's	11/21/2005	$ 908,000.00			
Small Business Phase II: CBIR Phase II: High Flux Metal-Ceramic Hydrogen Separation Membranes	3/6/2006	$ 925,292.00			
MOLECUALR BIOPHYSICS: Theoretical and Computational Studies of Pressure Induced Denaturation of Proteins	12/30/2005	$ 946,933.00			
ANALYSIS PROGRAM: Index Theory and the Baum-Connes Conjecture	5/22/2006	$ 900,000.00			
Small Business Phase II: SBIR Phase II: Single Step Chemical Mechanical Planarization of Copper/Ultra Low k Interconnects	8/1/2006	$ 977,173.00			
STEM TALENT EXPANSION PROGRAM (STEP): Increasing Numbers, Connections, and Retention in Science and Engineering (INCRSE)	8/15/2006	$ 980,204.00			
AERONOMY: Wind and Wave Patterns in the Earth's Ionosphere	11/15/2006	$ 985,351.00			
Collaborative Research: Center for Advanced Forestry Systems	8/29/2007	$915,834			
Brassinosteroid-auxin synergism to dissect hormone response pathways in Arabidopsis	7/1/2007	$920,000			
Laboratory for the Study of Extra Solar Planets: Fostering Data Literacy	9/24/2012	$990,674			

How Does Teachers' Visual Scaffolding Support Students' Mathematics Learning	8/10/2009	$999,798			
University of Arizona LSAMP Bridge to the Doctorate	8/20/2012	$987,000			
Simulations for Performance Assessments that Report on Knowledge and Skills (SPARKS)	4/30/2009	$942,501			
Collaborative Research: Initiation of a sex-determining chromosome: insights from sexually dimorphic strawberries	7/28/2010	$960,247			
New Approaches for Efficiency in Synthetic Organic Chemistry	2/23/2009	$942,500			
Bridge to the Doctorate	8/21/2012	$987,000			
California LSAMP Bridge to the Doctorate (BD) Activity	9/14/2012	$987,000			
Coordinating Office for Research on the Sedimentary Crust, Deep-Time and the Earth-Life System	3/20/2013	$975,707			
CC-NIE Integration: Supporting Climate Modeling Over Named Data Networking (NDN)	10/1/2013	$999,766			
Northeast LSAMP Bridge to the Doctorate	5/29/2014	$986,990			
Retinal Nanophotoswitch	8/6/2014	$900,000			
Greater Philadelphia Region LSAMP Bridge to the Doctorate (Cohort XI) Program	9/6/2013	$987,000			
SBIR Phase II: In Situ Optical Probe for Real-time Monitoring of Protein Expression Bioreactors	4/9/2014	$909,999			
2014-2016 Alabama Bridge to the Doctorate at the University of Alabama-Birmingham	7/12/2014	$987,000			
SBIR Phase II: Biodegradable Polymer Film for Sustained Delivery of Antibiotics to the Surface of the Eye	11/25/2014	$903,829			
III: Medium: Algorithms and Software Tools for Epigenetics Research	9/8/2013	$994,370			
2014 CSU-LSAMP Bridge to the Doctorate at California State University, Los Angeles	5/29/2014	$987,000			

How Does Teachers' Visual Scaffolding Support Students' Mathematics Learning	8/10/2009	$999,798			
University of Arizona LSAMP Bridge to the Doctorate	8/20/2012	$987,000			
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CURRICULUM VITA

MARTIAL STATUS: MARRIED

DATE OF BIRTH: 24 NOVEMBER 1965

PLACE OF BIRTH: SALINA, KANSAS

CURRENT RESIDENCE: BALTIMORE, MD

EDUCATION:

1983-1987 University of Maryland (UMBC) Baltimore, MD
B.A. Health Science & Policy/ Minor in Sociology

Anticipated December 2017 Johns Hopkins University Baltimore, MD
M.A.-Masters in Research Administration

WORK EXPERIENCE:

March 2009-Present Johns Hopkins University Baltimore, MD
Research Data Analyst at Johns Hopkins Hospital for the Pulmonary and Critical Care Unit

Current responsibilities include creating databases and surveys for a Cystic Fibrosis Consortium in order to collect data for multiple studies using the web based secure application REDCap. Additional tasks include providing Principal Investigators with weekly Recruiting/Retention Reports, Study Metrics Reports and Missing Data Reports.

Other duties consist of data management for three additional Medication Adherence Studies. Responsibilities include creating data sets, reports, managing data entry, data cleaning, and providing data analysis-using STATA.

2005-March 2009 Johns Hopkins University Baltimore, MD
Clinical Data Quality Assurance Specialist at Johns Hopkins Bayview Medical Center for the Diabetes Management Service

Responsibilities include creating databases for the service, monitoring the collection of inpatient/outpatient data, creating reports for statistical analysis, creating queries and assisting researchers with acquiring data, reconciling data, as well as assisting with the service's certification.

2005-March 2009 Johns Hopkins University Baltimore, MD

Clinical Research Coordinator at Johns Hopkins Bayview Medical Center

Responsibilities include coordinating daily activities related to the study such as study recruitment, marketing techniques, collecting study participants' data, tracking data, interacting with study participants, reconciling data, scheduling of visits and conducting administrative duties associated with the Internal Review Board and study sponsors.

2003-2004 Johns Hopkins University Baltimore, MD

Data Manager for the Medteams Study at Johns Hopkins Hospital Conducted by Dynamics Research

Responsible for collecting data, tracking missing data and reconciling data; as well as coordinating with the study manager to export data and resolve any discrepancies within database.

1990-2003 Johns Hopkins University Baltimore, MD

Research Programmer at Johns Hopkins University for the Department of Gynecology & Obstetrics

Responsible for creating the database for various entities within the department, collecting data, tracking missing data, reconciling data, data analysis and dissemination of data in statistical reports; as well as establishing protocols and procedures for data processing.

1988-1990 Johns Hopkins University Baltimore, MD

Data Coordinator for the Facts Study at Johns Hopkins University School of Public Health

Responsible for coordinating with data entry clerks at three research sites in a supervisory capacity in order to produce data that is accurate and thorough. Additional task include interviewing patients, collecting data, exporting data, reconciling data, data analysis, creating reports and conducting audits.